

What is claimed is:

1 1. A decoding method comprising:
2 receiving an encoded signal;
3 demodulating the received encoded signal to produce soft
4 information; and
5 iteratively processing the soft information with one or more
6 soft-in / soft-output (SISO) modules, at least one SISO module
7 using a tree structure to compute forward and backward state
8 metrics.

1 2. The method of claim 1 wherein the at least one SISO
2 computes the forward and backward state metrics by performing
3 recursive marginalization-combining operations.

1 3. The method of claim 2 wherein the recursive
2 marginalization-combining operations comprise min-sum operations.

1 4. The method of claim 2 wherein the recursive
2 marginalization-combining operations comprise min*-sum
3 operations.

1 5. The method of claim 4 wherein $\min^* = \min(x, y) - \ln(1 +$
2 $e^{-|x-y|})$.

1 6. The method of claim 2 wherein the recursive
2 marginalization-combining operations comprise sum-product
3 operations.

1 7. The method of claim 2 wherein the recursive
2 marginalization-combining operations comprise max-product
3 operations.

1 8. The method of claim 1 wherein the encoded signal
2 comprises at least one of a turbo encoded signal, a block turbo
3 encoded signal, a low density parity check coded signal, a
4 product coded signal, and convolutional coded signal.

1 9. The method of claim 1 wherein the encoded signal
2 comprises at least one of a parallel concatenated convolutional
3 code and a serial concatenated convolutional code.

1 10. The method of claim 1 further comprising using the
2 iterative decoding method in a wireless communications system.

1 11. The method of claim 1 further comprising terminating
2 the iterative processing upon occurrence of a predetermined
3 condition.

1 12. The method of claim 1 wherein the iterative processing
2 comprises performing parallel prefix operation or parallel suffix
3 operations, or both, on the soft information.

1 13. The method of claim 1 wherein the iterative processing
2 comprises using soft output of a first SISO as soft input to
3 another SISO.

1 14. The method of claim 1 wherein the tree structure used
2 by at least one SISO comprises a tree structure that results in
3 the SISO having a latency of $O(\log_2 N)$, where N is a block size.

1 15. The method of claim 1 wherein the tree structure used
2 by at least one SISO comprises a Brent-Kung tree.

1 16. The method of claim 1 wherein the tree structure used
2 by at least one SISO comprises a forward-backward tree.

1 17. The method of claim 16 wherein the forward-backward
2 tree comprises a tree structure recursion that is bi-directional.

1 18. The method of claim 1 wherein the processing performed
2 by at least one SISO comprises:

3 tiling an observation interval into subintervals; and

4 applying a minimum half-window SISO operation on each
5 subinterval.

1 19. The method of claim 1 wherein the iterative processing
2 comprises performing marginalization-combining operations which
3 form a semi-ring over the soft-information.

1 20. A soft-in / soft-out (SISO) module comprising:
2 a plurality of fusion modules arranged into a tree structure
3 and adapted to compute forward and backward state metrics,
4 wherein each fusion module is defined by the equation:

$$C(k_0, k_1) \triangleq C(k_0, m) \otimes_C C(m, k_1) \iff C(s_{k_0}, s_{k_1}) = \min_{s_m} [C(s_{k_0}, s_m) + C(s_m, s_{k_1})] \forall s_{k_0}, s_{k_1}$$

8 where $C(k, m)$ is a matrix of minimum sequence metrics (MSM)
9 of state pairs s_k and s_m based on soft-inputs between s_k and s_m .

1 21. The SISO module of claim 20 wherein at least one of the
2 fusion modules computes forward and backward state metrics by
3 performing recursive marginalization-combining operations.

1 22. The SISO module of claim 21 wherein the recursive
2 marginalization-combining operations comprise min-sum operations.

1 23. The SISO module of claim 21 wherein the recursive
2 marginalization-combining operations comprise min*-sum
3 operations.

1 24. The SISO module of claim 21 wherein $\text{min}^* = \min(x, y) -$
2 $\ln(1 + e^{-|x-y|})$.

1 25. The SISO module of claim 21 wherein the recursive
2 marginalization-combining operations comprise sum-product
3 operations.

1 26. The SISO module of claim 21 wherein the recursive
2 marginalization-combining operations comprise max-product
3 operations.

1 27. A soft-in / soft-out (SISO) module comprising:
2 one or more complete fusion modules (CFMs) for performing
3 marginalization-combining operations in both a forward direction
4 and a backward direction;
5 one or more forward fusion modules (fFMs) for performing
6 marginalization-combining operations only in the forward
7 direction; and

8 one or more backward fusion modules (bFMs) for performing
9 marginalization-combining operations only in the backward
10 direction,

11 wherein the one or more CFMs, fFMs, and bFMs are arranged
12 into a tree structure.

1 28. The SISO module of claim 27 wherein an amount of the
2 CFMs is a minimum number needed to compute a soft-inverse.

1 29. The SISO module of claim 28 wherein fFMs and bFMs are
2 used in the tree structure in place of CFMs wherever possible.

1 30. The SISO module of claim 27 wherein the
2 marginalization-combining operations performed by one or more of
3 the fusion modules comprise min-sum operations.

1 31. The SISO module of claim 27 wherein the recursive
2 marginalization-combining operations comprise min*-sum
3 operations.

1 32. The SISO module of claim 31 wherein $\min^* = \min(x, y) -$
2 $\ln(1 + e^{-|x-y|})$.

1 33. The SISO module of claim 27 wherein the recursive
2 marginalization-combining operations comprise sum-product
3 operations.

1 34. The SISO module of claim 27 wherein the recursive
2 marginalization-combining operations comprise max-product
3 operations.

1 35. The SISO module of claim 27 wherein the tree structure
2 comprises at least one of a Brent-Kung tree and a forward-
3 backward tree (FBT).

1 36. A method of iterative detection comprising:
2 receiving an input signal corresponding to one or more
3 outputs of a finite state machine (FSM); and
4 determining the soft inverse of the FSM by computing forward
5 and backward state metrics of the received input signal using a
6 tree structure.

1 37. The method of claim 36 wherein the forward and backward
2 state metrics are computed by at least one soft-in / soft-out
3 (SISO) module.

1 38. The method of claim 36 wherein the forward and backward
2 state metrics are computed using a tree-structured set of
3 marginalization-combining operations.

1 39. The method of claim 38 wherein the marginalization-
2 combining operations comprise min-sum operations.

1 40. The method of claim 38 wherein the marginalization-
2 combining operations comprise min*-sum operations.

1 41. The method of claim 40 wherein $\min^* = \min(x, y) - \ln(1 +$
2 $e^{-|x-y|})$.

1 42. The method of claim 38 wherein the marginalization-
2 combining operations comprise sum-product operations.

1 43. The method of claim 38 wherein the marginalization-
2 combining operations comprise max-product operations.

1 44. The method of claim 36 wherein the input signal
2 comprises at least one of a turbo encoded signal and a
3 convolutional coded signal.

1 45. The method of claim 36 wherein the input signal
2 comprises at least one of a parallel concatenated convolutional

3 encoded signal and a serial concatenated convolutional encoded
4 signal.

1 46. The method of claim 36 wherein determining the soft
2 inverse of the FSM comprises iteratively processing soft
3 information.

1 47. The method of claim 46 wherein the iterative processing
2 comprising performing parallel prefix operation or parallel
3 suffix operations, or both, on the soft information.

1 48. The method of claim 46 wherein the iterative processing
2 comprises using soft output of a first SISO as soft input to
3 another SISO.

1 49. The method of claim 37 wherein the tree structure used
2 comprises a tree structure that results in the SISO module having
3 a latency of $O(\log_2 N)$, where N is a block size.

1 50. The method of claim 36 wherein the tree structure
2 comprises a Brent-Kung tree.

1 51. The method of claim 36 wherein the tree structure
2 comprises a forward-backward tree.

1 52. The method of claim 51 wherein the forward-backward
2 tree comprises a tree structure recursion that is bi-directional.

1 53. The method of claim 37 wherein the at least one SISO
2 further:

3 tiles an observation interval into subintervals; and
4 applies a minimum half-window SISO operation on each
5 subinterval.

1 54. A turbo decoder comprising:
2 a demodulator adapted to receive as input a signal encoded
3 by a finite state machine (FSM) and to produce soft information
4 relating to the received signal; and
5 at least one soft-in / soft-out (SISO) module in
6 communication with the demodulator and adapted to compute a soft-
7 inverse of the FSM using a tree structure.

1 55. The decoder of claim 54 wherein the tree structure
2 implements a combination of parallel prefix and parallel suffix
3 operations.

1 56. The decoder of claim 54 further comprising at least two
2 SISO modules in communication with each other, wherein the SISO

3 modules iteratively exchange soft information estimates of the
4 decoded signal.

1 57. The decoder of claim 54 wherein at least one SISO
2 computes the soft-inverse of the FSM by computing forward and
3 backward state metrics of the received signal.

1 58. The decoder of claim 54 wherein the tree structure used
2 by at least one SISO comprises a tree structure that results in
3 the SISO having a latency of $O(\log_2 N)$, where N is a block size.

1 59. The decoder of claim 54 wherein the tree structure used
2 by at least one SISO comprises a Brent-Kung tree.

1 60. The decoder of claim 54 wherein the tree structure used
2 by at least one SISO comprises a forward-backward tree (FBT).

1 61. A method of iterative detection comprising:
2 receiving an input signal corresponding to output from one
3 or more block encoding modules; and
4 determining the soft inverse of the one or more block
5 encoding modules by computing forward and backward state metrics
6 of the received input signal using a tree structure.

1 62. The method of claim 61 wherein the forward and backward
2 state metrics are computed by at least one soft-in / soft-out
3 (SISO) module.

1 63. The method of claim 61 wherein the forward and backward
2 state metrics are computed using a tree-structured set of
3 marginalization-combining operations.

1 64. The method of claim 63 wherein the marginalization-
2 combining operations comprise min-sum operations.

1 65. The method of claim 63 wherein the marginalization-
2 combining operations comprise min*-sum operations.

1 66. The method of claim 65 wherein $\min^* = \min(x, y) - \ln(1 +$
2 $e^{-|x-y|})$.

1 67. The method of claim 63 wherein the marginalization-
2 combining operations comprise sum-product operations.

1 68. The method of claim 63 wherein the marginalization-
2 combining operations comprise max-product operations.

1 69. The method of claim 63 wherein the input signal
2 comprises at least one of a block turbo encoded signal, a low
3 density parity check coded signal, and a product coded signal.

1 70. The method of claim 63 wherein determining the soft
2 inverse of the block encoding module comprises iteratively
3 processing soft information.

1 71. The method of claim 70 wherein the iterative processing
2 comprising performing parallel prefix operation or parallel
3 suffix operations, or both, on the soft information.

1 72. The method of claim 70 wherein the iterative processing
2 comprises using soft output of a first SISO as soft input to
3 another SISO.

1 73. The method of claim 62 wherein the tree structure used
2 comprises a tree structure that results in the SISO module having
3 a latency of $O(\log_2 N)$, where N is a block size.

1 74. The method of claim 61 wherein the tree structure
2 comprises a Brent-Kung tree.

1 75. The method of claim 61 wherein the tree structure
2 comprises a forward-backward tree.

1 76. The method of claim 75 wherein the forward-backward
2 tree comprises a tree structure recursion that is bi-directional.

1 77. The method of claim 62 wherein the at least one SISO
2 further:

3 tiles an observation interval into subintervals; and
4 applies a minimum half-window SISO operation on each
5 subinterval.

1 78. A block decoder comprising:

2 a demodulator adapted to receive as input a signal encoded
3 by a block encoding module and to produce soft information
4 relating to the received signal; and

5 at least one soft-in / soft-out (SISO) module in
6 communication with the demodulator and adapted to compute a soft-
7 inverse of the block encoding module using a tree structure.

1 79. The decoder of claim 78 wherein the tree structure
2 implements a combination of parallel prefix and parallel suffix
3 operations.

1 80. The decoder of claim 78 further comprising at least two
2 SISO modules in communication with each other, wherein the SISO

3 modules iteratively exchange soft information estimates of the
4 decoded signal.

1 81. The decoder of claim 78 wherein at least one SISO
2 computes the soft-inverse of the block encoding module by
3 computing forward and backward state metrics of the received
4 signal.

1 82. The decoder of claim 78 wherein the tree structure used
2 by at least one SISO comprises a tree structure that results in
3 the SISO having a latency of $O(\log_2 N)$, where N is a block size.

1 83. The decoder of claim 78 wherein the tree structure used
2 by at least one SISO comprises a Brent-Kung tree.

1 84. The decoder of claim 78 wherein the tree structure used
2 by at least one SISO comprises a forward-backward tree (FBT).

1 85. An iterative detection method comprising:
2 receiving an input signal corresponding to one or more
3 outputs of a module whose soft-inverse can be computed by running
4 the forward-backward algorithm on a trellis representation of the
5 module; and

6 determining the soft inverse of the module by computing
7 forward and backward state metrics of the received input signal
8 using a tree structure.

1 86. The method of claim 85 wherein the input signal
2 comprises at least one of a block error correction encoded
3 signal, a block turbo encoded signal, a low density parity check
4 coded signal, and a product coded signal.

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